**Introduction**

Sustainable practices in earthmoving are methods, means, and inventions that make the earthmoving process more efficient and reduce its impact on the local and global environment. Sustainability in construction is important because the construction industry is a necessary part of providing shelter, energy, and living space for the world’s population. Construction is historically resource intensive and has a history of being an environment damaging process. Construction work needs to continue, but not in a manner that damages the world in which we live. Sustainable construction practices have been developed in construction and new processes to improve sustainability continue to be developed.

Sustainability in earthmoving is a very important topic because of its application to creating methods of sustainable construction. Earthmoving is the first step in any construction project and as such is a crucial part of construction. Some construction projects, such as water rerouting and embankment construction, consist entirely of earthmoving. Instituting sustainable practices in earthmoving will set a precedent for sustainable practices in the rest of the construction process.

**Definition**

Earthmoving is the practice of moving large amounts of soil to complete a construction project or prepare a site to begin a construction project. 1 Earthmoving equipment is the dump trucks, excavators, and bulldozers used in the earthmoving process. 2

**Historical Background**

**Ancient History**

The art of earthmoving first began with stone tools used by prehistoric man for rudimentary farming operations and home building. The only changes made in earthmoving through the times of the Romans and Renaissance was in the tools used for earthmoving. The iron and copper ages gave the farm laborers of medieval times better tools to work with, but earthmoving was still largely done by hand or through carts pulled by animals. The amounts of earth moved were small and the impact on the environment was minimal. These forms of earthmoving were highly sustainable, but very inefficient. Impressive amounts of earth were moved by the ancients, creating structures such as the Serpent Mound in Ohio, built by Ancient Native Americans.

**Steam Power**

The advent of steam power in the 1800’s changed earthmoving on a fundamental level. For the first time in history, a human being could use a powered machine to move greater volumes of dirt at faster rates. Mobile steam shovels and steam-powered tractors fitted with bulldozer blades gave new, more efficient, techniques to earthmovers of the 1800s. The use of coal as fuel for the steam-powered machines and the use of explosives to facilitate earthmoving began to make a larger impact on the environment. Coal is a non-renewable resource and while the reserves contained in the earth are large, they do have a limit.

**Modern Era**

After the invention of the internal combustion engine; the amount of earth that workers were able to move in a work period increased dramatically. The uses of diesel fuels, and continuing inventions in mechanical efficiency and power have revolutionized the earth moving industry. At the same time, however, these advances have also changed how earthmoving impacts the environment. The use of diesel fuel releases pollution particles and atmosphere harming emissions. The act of earthmoving can pollute streams and rivers and harm ecosystems. As earthmoving processes have increased their output, they have also increased their impact on the environment. In response to increased environmental awareness, advancements have been made in increasing earthmoving sustainability. 3

**Sustainability Improvements**

Creating sustainable earthmoving falls into two categories. The first is earthmoving practice; changing how earthmoving is performed to create a more sustainable environment. The second is earthmoving efficiency; changing how earthmoving consumes energy to create a more sustainable use of energy.

**Sustainability in Earthmoving Practice**

Sustainable earthmoving practice mostly consists of operating earthmoving equipment in ways that avoid damaging the environment in which the earthmoving is being performed.

An important aspect of sustainability is protecting natural resources. Earthmoving can affect water resources by destroying stream banks and allowing soil to pollute waterways by performing earthmoving too close to rivers and streams. Dust stirred up from earthmoving operations can also become an airborne pollutant and be carried by the wind into streams and lakes. Earthmoving practices that can be used to protect water resources include dampening the soil before earthmoving can also prevent air pollution. Marking the edges of streambeds and banks will alert the equipment operator and help him avoid damaging them. 4

After earthmoving practices in an area are completed, soil runoff is typically increased due to compaction and/or structures and concrete that was added to the site. This soil runoff can increase the amount of sediment that pollutes rivers and waterways. A way to prevent this is to build sediment fences along the waterway bank or in the drainage system to prevent construction dust and debris from polluting local waterways.

When earthmoving disturbs topsoil and removes vegetation, soil erosion is accelerated. Soil erosion is especially accelerated during rainy seasons. Prevention and mitigation of soil erosion is paramount to sustainability. Reducing vegetation removal as much as possible and replanting temporary and permanent vegetation as soon as possible after the completion of the project can greatly reduce soil erosion. Replacing topsoil in disturbed areas after project completion will encourage the growth of local plants and provide moisture capacity and protection for the soil. Again, marking the edges of the site to avoid unnecessary vegetation disturbance through root damage and plant damage can reduce vegetation destruction.

Disposal of waste materials from earthmoving sites is another aspect of earthmoving where sustainability can be improved. Soil banks both on the jobsite and off can be covered with tarps to reduce air pollution and soil runoff. Contaminated waste soil from areas where vehicles were parked or maintenance was performed needs to be removed to prevent engine fluids and fuel from leaching into water sources. Waste brush and wood products can also be disposed of in an environmentally friendly manner instead of simply burning them onsite. 5

**Sustainability in Earthmoving Equipment**

Most of the recent sustainability developments in earthmoving have been made in reducing particulate matter and nitrogen oxide emissions from vehicle exhaust and increasing fuel and vehicle efficiency.

2010 Emission Regulations require heavy and medium use diesel powered vehicles to reduce their particulate matter and oxide of nitrogen emissions. Diesel engine manufactures developed a method of emission reduction known as Selective Catalytic Reduction, or SCR, to meet these requirements. Selective Catalytic Reduction uses a mixed water and urea fluid known as Diesel Exhaust Fluid, or DEF, and mixes it with the engine exhaust to reduce these emissions. 6 The use of SCR and DEF in diesel engines reduces emission pollution by 90%. 7

Sustainability of earthmoving equipment can be greatly improved by the use of biodiesel and “clean” diesel in earthmoving equipment. “Clean” diesel contains less sulfur than regular diesel. This helps vehicle manufacturers install better emission control solutions such as SCR and is also healthier for construction workers. 8

Biodiesel is a recent and exciting development in the earthmoving industry and provides a number of benefits to the use of earthmoving equipment. The development of an ASTM standard for the purity of biodiesel made the alternative much more appealing to construction companies. 9 Biodiesel improves the sustainability of earthmoving equipment by reducing the use of non-renewable oils as fuel. Biodiesel is an entirely sustainable fuel since it is made from organic crops. In the future, earthmoving vehicles may run entirely on sustainable biodiesel, greatly increasing the sustainability of earthmoving. 10

Another recent sustainability development in earthmoving is the invention of hybrid engines and electric drives for earthmoving equipment. Hybrid engines combine diesel engines with electric power, which greatly reduces the diesel fuel used by the equipment. In combination with recent mechanical inventions that improve efficiency; hybrid engines can greatly reduce fuel usage and improve earthmoving sustainability.

**Advantages of Sustainable Earthmoving**

Sustainable earthmoving offers a number of advantages to construction companies that choose to run their business in a sustainable manner.

Company reputation and recognition will be greatly improved when customers see that a business cares about protecting the world in which they live. In many cases, companies report that they get more work because of their sustainable practices. Sustainable earthmoving will also reduce potential fines and fees that a company might have to pay to the Environmental Protection Agency if it is found that they are practicing non-sustainable earthmoving.

In addition to reputation, the use of sustainable practices, especially biodiesel and hybrid engines, greatly reduces fuel costs for earthmoving vehicles. Biodiesel is actually cheaper than regular diesel. Biodiesel also has less carcinogens and emissions, which greatly increases the health and well being of equipment operators and mechanics. 11 Hybrid and electric drive machines can reduce fuel consumption by as much as 40%, making them a very attractive option for construction companies. 12 Use of sustainable practices and reduced emission equipment can also result in monetary refunds or bonuses from the Environmental Protection Agency or from environmentally conscious customers.

**Disadvantages of Sustainable Earthmoving**

Some disadvantages of sustainable earthmoving can be the time and money that it takes to switch from diesel engines to biodiesel use or the additional cost of reducing soil erosion and preventing water pollution. The additional costs can usually be quickly balanced by the added efficiency of hybrid engines, the lower cost of biodiesel, the reduction in possible EPA fines, and in additional business brought to the company by sustainable practices. 13

**Examples of Sustainable Practice**

K&E Excavating based in Salem, Oregon ran tests on a hybrid engine dozer, the CAT D7E to test fuel consumption compared to their previous dozer, the D7R Series 2. They found that using the D7E would save them $6,720 a month in fuel costs per machine. They also reported that their use of biodegradable hydraulic oil won them jobs for the Oregon Department of Transportation and other companies that would not have hired them without their use of sustainable equipment. 14

On Oct. 31,2013 Caterpillar Inc. received the 2013 Illinois Governor’s Sustainability Award for the design and construction of the 336E H Hybrid Excavator. The hybrid electric machine is reported by CAT to use 50% less fuel at the same output than its former counterpart, the 336D. 15

**Continuing Research**

Further research in sustainability of earthmoving operation consists of two main parts. Manufacturers such as CAT and Komatsu are continuing to improve their hybrid engines and find ways to store excess engine electricity for use when the machine demands peak power. Mechanical parts and systems to improve engine efficiency are also under examination. 16 17

Fuel companies are working to make bio-diesel a more attractive option to construction companies while also researching other alternative fuels like propane and compressed natural gas. 18 19

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